Fasted exercise does not improve postprandial lipemia responses to different meals in adolescents: a randomized crossover clinical trial

El ejercicio en ayunas no mejora las respuestas de la lipemia posprandial a diferentes comidas en adolescentes: un ensayo clínico cruzado aleatorizado

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Abstract

Background: Prolonged postprandial hyperlipemia (PPL) and hyperglycemia (PPG) are important risk factors for the development of cardiovascular disease. Although physical exercise improves lipid profile and glucose tolerance, thus reducing cardiovascular risk, the effects of fasting exercise in adolescents need to be investigated. Objective: We investigated the effects of different intensities of fasted aerobic exercise on the magnitude of PPL and glycemic responses to isocaloric meals in adolescents. Methods: A randomized crossover clinical trial in which 13 healthy and eutrophic adolescents, aged 14.5 ± 1.3 years, performed three interventions (washout period = 7 days): 45 minutes of rest (REST); 45 minutes of moderate-intensity fasting (MI); and a calorie-matched high-intensity aerobic exercise session (HI). Subjects were serially assessed for blood triglycerides, cholesterol, and glucose levels. Results: Regarding PPL, the MI protocol induced triglycerides reductions compared to REST only at 105 min (70.1 ± 10.3 vs 95.4 ± 30.2; p=0.006) and compared to both HI and REST at 135 min (68.4 ± 14.4 vs 91.5 ± 24.9 vs 93.7 ± 21.2 p<0.02). No differences in iAUC were observed. Conclusion: Calorie-matched moderate and high-intensity fasting aerobic exercise has no acute effect on PPL responsiveness in adolescents.

Keywords

Hyperglycemia; Exercise Intensity; Hyperlipidemias; Child; Adolescent Nutrition.

Resumen

Antecedentes: La hiperlipemia posprandial prolongada (PPL) y la hiperglucemia (PPG) son factores de riesgo importantes para el desarrollo de enfermedades cardiovasculares. Aunque el ejercicio físico mejora el perfil lipídico y la tolerancia a la glucosa, reduciendo así el riesgo cardiovascular, es necesario investigar los efectos del ejercicio en ayunas en adolescentes. Objetivo: Investigar los efectos de diferentes intensidades de ejercicio aeróbico en ayunas sobre la magnitud de la PPL y las respuestas glucémicas a las comidas isocalóricas en adolescentes. Métodos: Ensayo clínico aleatorizado cruzado en el que 13 adolescentes sanos y eutróficos, de 14,5 ± 1,3 años de edad, realizaron tres intervenciones (período de lavado = 7 días): 45 minutos de descanso (REST); 45 minutos de ayuno de intensidad moderada (MI); y una sesión de ejercicio aeróbico de alta intensidad (HI) con calorías equivalentes. Se evaluaron en serie los niveles de triglicéridos, colesterol y glucosa en sangre de los sujetos. Resultados: En cuanto a la PPL, el protocolo MI indujo reducciones de triglicéridos en comparación con REST solo a los 105 min (70,1 ± 10,3 frente a 95,4 ± 30,2; p = 0,006) y en comparación con HI y REST a los 135 min (68,4 ± 14,4 frente a 91,5 ± 24,9 frente a 93,7 ± 21,2 p < 0,02). No se observaron diferencias en iAUC. Conclusión: El presente estudio muestra que el ejercicio aeróbico en ayunas de intensidad moderada y alta con calorías emparejadas no tiene un efecto agudo en la respuesta de PPL en adolescentes.

Palabras clave

Hiperglucemia; Ejercicio Intensidad; Hiperlipidemias; Niño; Nutrición del Adolescente.

Introduction

The worsening lifestyle of children and adolescents is a growing concern because of the potential adverse health effects. For example, the worst dietary habits are associated with sedentary lifestyles, increased screen time and poor sleep among adolescents, which could lead to an increased risk of several chronic diseases (Ji et al., 2024). In this context, adolescents often consume ultra-processed foods, which are characterized as industrial formulations, often rich in added sugars, saturated fats, salt and additives, resulting in increased PPL and PPG. Therefore, preventive measures at an early age should be encouraged and incorporated into school health programs (Pearson et al., 2022).

Although exercise is an important tool to mitigate PPL and PPG responses to high-fat meals, most studies have been conducted in adults, and the effects of exercise on PPL in children and adolescents remain to be investigated (Ji et al., 2024). Of note, when the effect of exercise on PPL is compared to a control (i.e., resting) condition, statistically significant differences are found in most studies conducted in adolescents, although the magnitude of the reductions varies (Pearson et al., 2022).

Intensity is an important factor in exercise prescription and its manipulation influences PPL responses (Pontes-Silva, Lopes, Teixeira, et al., 2023). Furthermore, exercise performed at low intensities does not seem to be effective in attenuating the lipemic curve, especially when compared to exercise performed at moderate and high intensities (Ji et al., 2024). Most evidence suggests that moderate-intensity exercise attenuates postprandial triglyceridemia in both boys and girls. Although some studies have shown various beneficial effects of exercise on lipid and glucose metabolism in this population there is no consensus on the intensity threshold that determines the beneficial role of exercise (Pearson et al., 2022).

Similarly, fasted exercise has been proposed as a strategy to improve lipid oxidation during and after exercise, although responses could be influenced by several factors (Pontes-Silva & Lopes, 2024), including body composition (Takla et al., 2024). Nonetheless, studies of fasted exercise and PPL responses in adolescents are scarce. Due to increased triglyceride mobilization, lipoprotein lipase enzyme activity and fatty acid oxidation (Maciel et al., 2022).

This study makes a novel contribution to the field by emphasizing the importance of regulating intensity during exercise performance and the critical role of diet in the pre-exercise period. There is a consistent lack of consensus in the literature regarding the optimal intensity and training model for adolescents. To address this knowledge gap, the study aims to elucidate the differences between different intensity levels (Galeano-Muñoz et al., 2024).

Given the evidence that PPL is a risk for chronic disease in adolescents and that exercise may be a protective factor depending on its intensity, the aim of this study was to investigate the effects of different intensities of fasted aerobic exercise on the magnitude of PPL and glycemic responses to isocaloric meals in adolescents.

Methods

Design and ethical aspects

A randomized crossover clinical trial in which 13 healthy and eutrophic adolescents, aged 14.5 ± 1.3 years, eutrophic and healthy male adolescents were recruited through social media (Table 1). The study was approved by the Research Ethics Committee of the Federal University of Rio Grande do Sul (report number 376.550), and all signed a free and informed consent form, and the legal guardians signed an informed consent form (ClinicalTrials.gov number: NCT00929890). We included participants between 12 and 16 years of age, eutrophic based on body mass index, healthy, non-smokers, without chronic diseases, and not using appetite suppressants in the last six months (Pontes-Silva, Lopes, Maciel, et al., 2023).

Participants first underwent a basal metabolic rate test, anthropometric assessment, self-assessment of biological maturity, and an exercise test to determine peak oxygen uptake. Subjects were then assigned to exercise protocols: moderate intensity (MI), high intensity (HI), and rest. In order to match the total

energy expenditure with the moderate-intensity session, the high-intensity exercise session was performed last. However, the order of rest and moderate-intensity was randomized using a special website (randomizer.org).

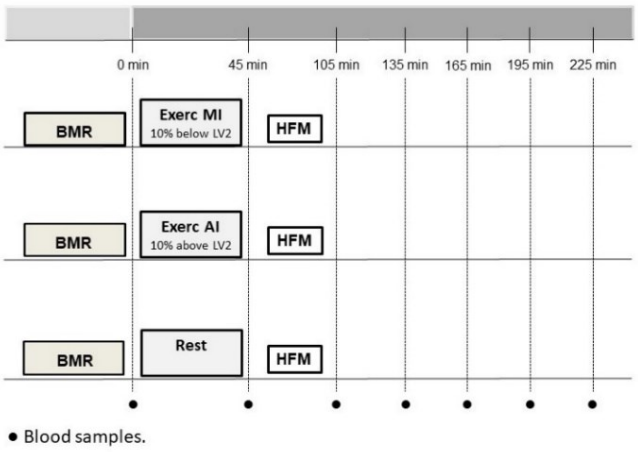
For all sessions, subjects arrived at the laboratory at 7:30 am and performed the corresponding exercise protocol. Subsequently, participants consumed a high-fat meal (30% carbohydrates, 60% lipids, and 10% protein) and underwent blood sampling every 30 minutes for a total of 7 samples of 5 ml each. A minimum of one week was allowed between sessions to avoid residual effects from the previous session (Figure 1).

Table 1. Participant's characteristics.

n=13	Mean ± Standard Deviation
Age (Years)	14.5 ± 1.3
Body mass (kg)	60.1 ± 13.4
Stature (cm)	170 ± 0.1
BMI (kg/m^2)	20.3 ± 3.2
Sum of 6 skinfolds (mm)	89.1 ± 42.3
VO_{2peak} (ml.kg.min^{-1})	30.3 ± 6.8
Stage of Tanner: Genital*	4 (3-5)
Stage of Tanner: Pubertal	5 (3-5)
Energy value of meals (kcal)	848.7 ± 199.23

BMI: Body mass index (specific for children); VO_{2peak}: Peak oxygen consumption; Sum of skinfolds: triceps, subscapularis, supraspinatus, abdominal, thigh and calf; The values of the maturational self-assessment are presented in median.

Figure 1. Study design. BMR: Basal Metabolic rate; HFM: High fat meal; MI: Moderate intensity; HI: High intensity.



Body composition

Body composition was calculated using the five-component method. Skinfolds were measured with a caliper (Harpenden scientific model, Cescorf, Porto Alegre, Brazil), girth was measured with a tape measure (Sanny, São Bernardo do Campo, São Paulo), weight and height were measured with scales and a stadiometer (Uranus, ref. OS-180, RS / Brazil). Data were collected by an experienced level III evaluator according to the recommendations of the International Society for the Advancement of Kinanthropometry (Lopes et al., 2025).

Sexual Maturation

The self-assessment was conducted using the Sexual Maturity Rating, in a separate room where the assessors received prior instructions on how to use the form with drawings. The form contained brief explanatory text about the developmental characteristics of the genitals and pubic hair at each stage of maturation. After the preliminary explanations, the raters, individually in possession of the form, identified the stage of development that was closest to their personal image (Guidi & Sapra, 2025).

Basal metabolic rate

Subjects were instructed to avoid physical activity on the day before the test and to fast for 12 hours with at least 8 hours of sleep during the night, and not to consume alcohol, caffeine, or any type of medication during this period without prior notification to the research team. Water consumption was ad libitum. All basal metabolic rate tests were performed between 7:30 am and 8:30 am in a room temperature between 20°C and 25°C with controlled noise and low light. The protocol consisted of 10 minutes of rest on a stretcher in the supine position followed by 30 minutes of gas acquisition. A gas analyzer (MedGraphics Cardiorespiratory Diagnostic Systems, model CPX-D) was used to determine VO_2 and VCO_2 values. To calculate basal metabolic rate, the first 10 min of uptake were discarded and the mean values of VO_2 and VCO_2 ($L.min^{-1}$) of the following 20 min were used. To obtain kcal/day values, the equation proposed by Weir, 1949, was used: $[(3.9 \text{ X } VO_2) + (1.1 \text{ X } VCO_2)] \text{ x } 1440$ (Lopes et al., 2021).

Maximal oxygen peak

Maximum oxygen uptake (VO_{2max}) was determined using an open-circuit gas analyzer (MGC, model CPX/D). Maximal exercise tests were performed on a bicycle ergometer (The Bike, Cibex, USA) with an initial intensity of 25 watts (W) and an increase of 25 W per minute (25 W min^{-1}), maintaining a pedaling cadence of 70 to 80 revolutions per minute. A telemetric belt was positioned to continuously monitor the participants' heart rate (S610, Polar Electro Oy, Finland). Subjects reported perceived exertion for each increase in intensity and were verbally encouraged to exert maximum effort during the test. The test lasted 8-12 min according to the recommendations of the American College of Sports Medicine and ended when the participants reached one of the following criteria (a) plateau in oxygen peak; (b) heart rate ≥ predicted for age; (c) respiratory exchange rate value > 1.15; (d) perceived exertion > 18; or when the subject voluntarily requested to stop the test (Lopes et al., 2021; Pontes-Silva et al., 2024).

Dietary control

All subjects were instructed to avoid alcoholic beverages and/or caffeine-containing products for at least 48 h prior to the protocols. At the baseline visit, subjects were individually instructed to complete two 24-hour dietary recall forms (for two days per week), which were returned to the dietitian for analysis of dietary composition. Each participant recorded all foods and beverages consumed on the days preceding the protocols. Twenty-four hours prior to the protocols, subjects repeated the same food peak described in the first record. Data analysis was performed using Dietwin® (Brubins) software, professional version (2008).

Testing sessions and high-fat meal

The exercise protocols were performed on a bicycle ergometer as follows: the MI and REST protocols lasted 45 minutes, and the HI protocol ended when the subject reached the energy expenditure corresponding to the MI expenditure, which was controlled by calculating metabolic equivalents in real time (Carteri et al., 2016; Pontes-Silva, Kovaleva, Gadzhiakhmedova, et al., 2023).

During the first five minutes, the subjects started to warm up until they reached the target zone, which corresponded to 10% below the 2nd ventilatory threshold in MI and 10% above the 2nd ventilatory threshold in HI. In the REST, the subjects were to remain for the same period without the practice of physical exercise, being free to use electronic devices. Water consumption was recorded during the protocols, and oxygen consumption and carbon dioxide production, as well as heart rate, were measured by ergospirometry and telemetry, respectively (Carteri et al., 2016; Pontes-Silva, 2022).

To determine energy expenditure, subjects used the same equipment and sat on the cycle ergometer for 5 minutes before beginning the protocols. Total energy expenditure was calculated as the sum of absolute measured VO_2 ($l.min^{-1}$) for each minute during the protocols (excluding the first 5 minutes), multiplied by 3.5 (to obtain metabolic equivalents), which were multiplied by 5.0 ($kcal.L^{-1}$) (Carteri et al., 2016).

Post-exercise oxygen consumption was not considered in determining the caloric content of the meal. To report the energy expenditure of exercise, the mean of the two sessions is presented. The meal consisted of a milkshake consisting of ice cream, cream, and skim milk, which was composed of 30% carbohydrates, 60% lipids, and 10% protein. The high fat meal was formulated to create an isoenergetic state. The basal metabolic rate was previously determined from metabolic equivalents (METs). Subjects were

given 10 minutes to consume the meal and 50 minutes to digest it, for a total of 60 minutes (Carteri et al., 2016).

Blood samples and Biochemical analysis

Blood samples were obtained before basal metabolic rate assessments using a hypodermic needle and syringe for a total of 5 mL from an antecubital vein. Blood samples were obtained during the experimental protocols by inserting a cannula (flexible polyvinyl chloride polymer, Teflon®) into an antecubital vein. Saline was infused every 5 minutes to maintain free access for collection. A total of 8 blood samples (pre-protocol, premeal, 1 h postmeal, and 5 subsequent samples; 10 mL each) were obtained, and the total sampling time was 255 minutes (Carteri et al., 2016).

The procedure was performed by a trained professional using disposable equipment. The levels of triglycerides, total cholesterol, HDL-cholesterol and plasma glucose were determined by enzymatic colourimetric method (Advia Bayer®), and LDL-C was estimated using the Friedewald formula. The area under the curve (AUC) of postprandial lipemia was calculated using the trapezoidal method as previously described (Friedewald et al., 1972).

Statistical analysis

The data were structured and analyzed using SPSS, version 26.0 for Windows. Normality of distribution for all variables was assessed using the Shapiro-Wilk test, and homoscedasticity of variances was assessed using Levene's test. Exercise protocols (MI and HI) for duration, heart rate, respiratory exchange rate, and energy expenditure using Student's t-test for independent samples. To isolate the effects of exercise and meal on both triglycerides and glucose responses, deltas were calculated: Postexercise – baseline / baseline, and 8h postmeal – baseline / baseline, expressed as percentages.

These variables and the time points of postprandial differences between different treatment groups were analyzed using two-way repeated measures ANOVA with Bonferroni post hoc. We calculated incremental AUC for triglycerides and glucose, which were compared using one-way ANOVA with Tukey's post hoc test. To isolate the effects of exercise and meal on both triglycerides and glucose responses, we calculated deltas: Postexercise – baseline / baseline and 8h postmeal – baseline / baseline, expressed as percentages. The results are expressed as mean and standard deviation, and the significance level was $p>0.05$.

Results

These results are very important because they show that HI was indeed more intense than MI, which is fundamental for comparing the protocols. Table 2 shows that the variables related to exercise intensity were higher in the HI protocol compared to MI, average VO_{2peak} (25.6 + 4.97 vs 20.0 + 3.96 ml.kg.min^{-1}; p=0.005), heart rate (167.35 + 7.1 vs 155.94 + 17.7 bpm; p=0.03) and respiratory exchange rate (1.02 + 0.02 vs 0.95 + 0.05; p=0.001). Regarding session duration, the HI protocol was shorter compared to the MI protocol (27.0 + 1.6 vs 45 + 1.3 min; p=0.001).

Another important result was that there were no differences in energy expenditure, so we were able to attribute the differences found in the variables only to the exercise protocols and not to the energy cost caused by them (p=0.89).

Table 2. Comparison between protocols in exercise responses.

	Moderate Intensity	High Intensity	*p*
Average VO_2 (ml.kg.min^{-1}) *	20.0 ± 3.96	25.6 ± 4.97	0.005
Session duration (min) *	45 ± 1.3	27 ± 1.65	0.001
Energy expenditure (kcal)	204.5 ± 45.20	202.42 ± 34.70	0.89
Heart rate (BPM) *	155.94 ± 17.73	167.35 ± 7.11	0.03
Respiratory exchange rate (RER) *	0.95 ± 0.05	1.02 ± 0.02	0.001

VO_2: maximum oxygen peak; Kcal: kilocalories; BPM: beats per minute.

Figure 2 (A) shows the effect of MI on triglyceride reduction compared to REST at 105 min (70.1 ± 10.3 vs. 95.4 ± 30.2; p=0.006). A subsequent analysis of a 135-minute post-meal period showed that MI had

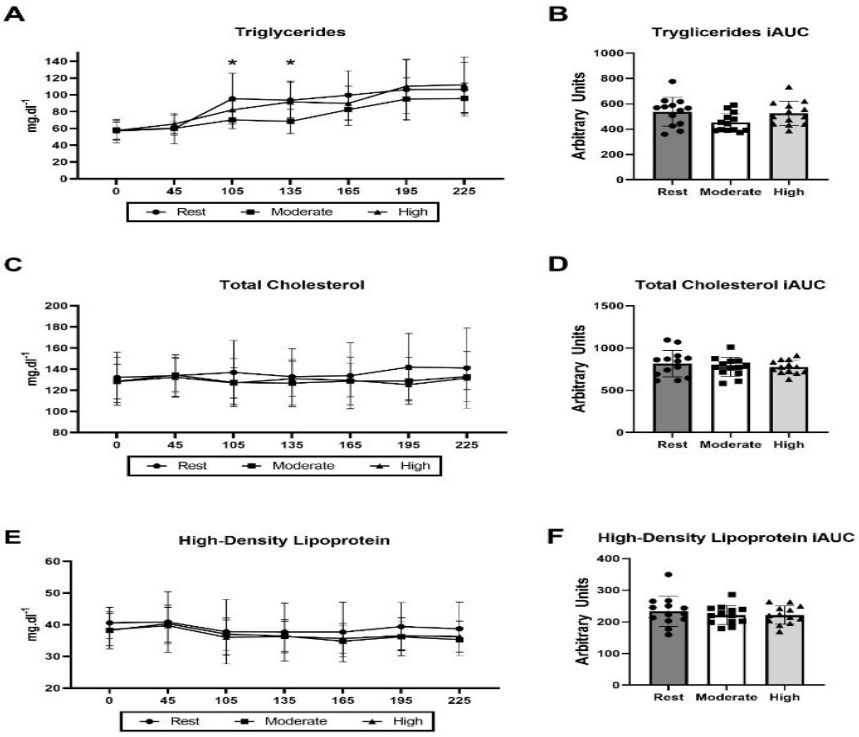
a discernible effect compared to HI and REST, underscoring the efficacy of MI as a viable exercise modality. (68.4 ± 14.4 vs 91.5 ± 24.9 vs 93.7 ± 21.2 p<0.02). Regarding the effect of time, differences were observed at all time points compared to 0 min (p<0.05), as detailed in Table 03. No differences were observed for total cholesterol or HDL concentrations at the time points evaluated (Figure 2C and 2E). Similarly, no differences were found when analyzing the incremental area under the curve of triglycerides, total cholesterol and HDL (Figure 2A, 2B, 2D and 2F, respectively).

Table 3. Two-way ANOVA and for scored responses

Variables	Triglycerides		Glucose		Total Cholesterol		High-desnsity Lipoprotein	
	F (DFn, DFd)	*p*	F (DFn, DFd)	*p*	F (DFn, DFd)	*p*	F (DFn, DFd)	*p*
Interaction	F (12, 216) = 1.800	0.0496	F (12, 216) = 4.516	0.0001*	F (12, 216) = 0.8989	0.5489	F (12, 216) = 0.5069	0.9091
Time	F (6, 216) = 47.33	0.0001*	F (2.983, 107.4) = 5.090	0.0025*	F (2.955, 106.4) = 1.229	0.3029	F (2.942, 105.9) = 8.888	0.0001*
Column	F (2, 36) = 2.463	0.0994	F (2, 36) = 1.134	0.3330	F (2, 36) = 0.4605	0.6346	F (2, 36) = 0.5200	0.5989
Subject	F (36, 216) = 6.278	0.0001*	F (36, 216) = 4.262	0.0001*	F (36, 216) = 22.19	0.0001*	F (36, 216) = 23.64	0.0001

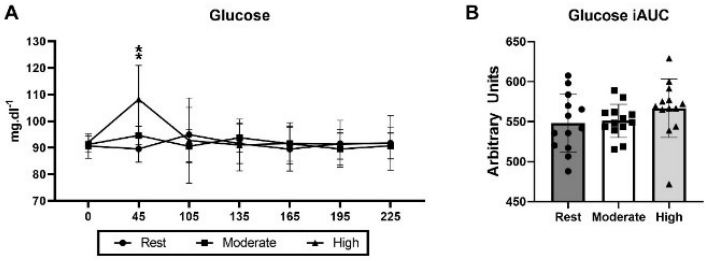
*Significant differences

Figure 2. Responses of triglyceride concentrations (A) and incremental area under the curve of triglycerides (B) at different time points. *Significant difference between REST and MI at 105 and significant difference between MI, REST and HI at 135. No differences were observed for total cholesterol (C) and high-density lipoprotein (E) and the incremental area under the curve for these variables (D and F, respectively).



When analyzing the glucose data, effects of the HI protocol were found compared to MI and REST at the 45-minute time point (108.2 ± 12.7 vs. 94.6 ± 3.4 vs. 89.5 ± 4.9; p=0.001). There was an effect of time at all times compared to the 45 min time point (p=0.031) as shown in Figure 3A and detailed in Table 3. No differences were found for the incremental area under the curve (Figure 3B).

Figure 3. Glucose concentrations at different time points (A) and incremental area under the curve (B). *Significant difference between groups at 45 minutes.



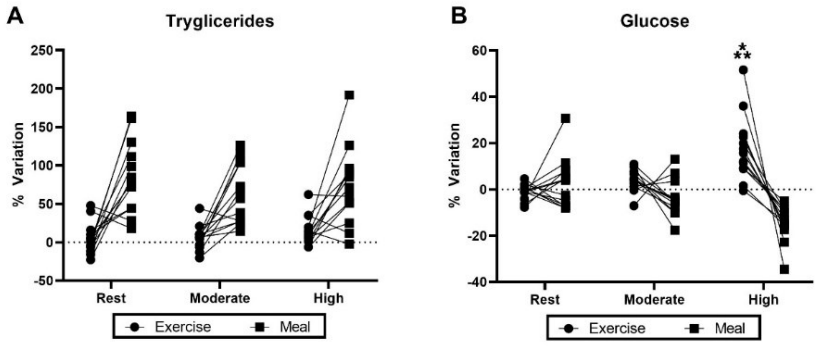
The individual percentage variations for triglyceride and glucose responses after exercise and meals are shown in Figure 4. Specific effects are described in Table 04. A significant difference between groups was found for the post-meal glucose curve after the HI protocol, which showed a higher percentage variation compared to both REST and MI when baseline values were used as reference (Figure 4 B; p = 0.0001 for both comparisons).

Table 4. Two-Way ANOVA and for individual variations

Variables	Triglycerides		Glucose	
	F (DFn, DFd)	*p*	F (DFn, DFd)	*p*
Interaction	F (2, 36) = 0.8072	0.4540	F (2, 36) = 17.66	0.0001*
Time	F (2, 36) = 1.057	0.3580	F (2, 36) = 0.5364	0.5895
Column	F (1, 36) = 54.47	0.0001*	F (1, 36) = 23.02	0.0001*
Subject	F (36, 36) = 0.6319	0.9134	F (36, 36) = 0.2684	0.9999

*Significant differences

Figure 4. Individual variation of tryglicerydes (A) and glucose responses (B). induced by each session and after the meal. The high intensity protocol showed significant (*) higher percentual variation when baseline values were taken as reference for glucose responses.



Discussion

The present study investigated the acute effects of moderate and high intensity exercise on postprandial lipemia and glycemia in healthy eutrophic adolescents. Our main findings from this study were: (1) no differences in iAUC responses after MI and HI protocols compared to rest; (b) there was a reduction in TG levels in the MI protocol compared to REST and HI at minutes 105 and 135, and at minute 165 between REST and MI; (c) the HI protocol caused a greater individual percentage change in post-exercise glycemia. Our results are consistent with the literature showing that a single exercise session is capable of significantly reducing PPL in adults and children.

Postprandial lipemia is a complex physiological phenomenon that has not yet been fully described in the literature. The first work suggesting that PI is related to atheromatous plaque formation dates back

to 1947, and consequently it has been associated with cardiovascular disease. Persistently high triglyceride levels after a high-fat meal have been associated with an abnormal metabolic response and ultimately with an increased likelihood of morbidity and mortality (Al-Mousa et al., 2023).

To study PPL, it is necessary to consume a standardized meal, usually consisting of an average of 55% lipids, 35% carbohydrates, and 10% protein, in solid or pasty form (Pearson et al., 2022). However, studies using higher percentages of lipids have shown similar responses in adolescents regardless of the amount of fat, a fact not seen in adults; also, the higher the percentage of lipids in the meal, the longer it takes for triglycerides to be metabolized (Al-Mousa et al., 2023). In addition, regarding the chosen intensity, numerous studies investigating PPL responses to exercise present protocols with different intensities and volumes (Pearson et al., 2022).

In particular, most of these studies use percentages of VO_{2max}, which may be inaccurate due to individual metabolic differences. In addition, different individuals may have very different metabolic conditions regardless of whether they are working at the same percentage of VO_{2max}. In addition, the present study aimed to standardize metabolic intensity using the ventilatory threshold for exercise prescription, which is considered the best parameter to control individual metabolic load (Rothschild et al., 2022).

Furthermore, most studies investigated adults, and the effects of exercise intensity on LPP in children and adolescents are still poorly explored. The present study demonstrates that in adolescents between 12 and 16 years old, neither moderate nor high-intensity exercise caused effects in PPL, with a peak between 2 and 4 hours after a meal. Likewise, few studies also verified the same peak times of the triglyceride curve (Pearson et al., 2022), contrasting with the studies carried out in adults. This phenomenon is partially explained by a greater metabolic activity in young people, which would facilitate the removal of these lipids in a shorter period of time (Jiménez-Martínez et al., 2023).

Notably, lower intensities were not examined in the present study, although some studies in adults suggest that these intensities are not sufficient to alter the postprandial triglyceride curve. Of note, Katsanos et al. conducted a study in 13 healthy men comparing two different intensities with the same caloric expenditure (low intensity - 25% VO_{2peak}, with a duration of 237 minutes, and moderate – 65% VO_{2peak}, with a duration of 90 minutes) and reported significant reductions in the triglycerides curve only after moderate intensity exercise. One of the possible explanations for this reduction is the greater activity of the enzyme lipoprotein lipase, mediated by a lower release of insulin as a result of moderate intensity, which does not occur at lower intensities (Wang et al., 2022).

Notably, in our study, a glucose peak occurred at minute 45 in the HI protocol. Although we did not assess insulin levels, it is possible that this glycemic peak may have stimulated its release, thereby decreasing the activity of the LPP enzyme, which would explain the lower efficiency of high-intensity exercise in decreasing LPP in our study. Also, this significant glycemic peak may have been mediated by increased glucagon secretion, activating glycogenolysis (Ren et al., 2022).

This may explain the responses reported in the present study. Furthermore, when the effects of two exercise protocols at 55% of VO_{2peak} (30min or 60min, with an expenditure of 234kcal and 469kcal) were studied in young boys, a reduction in the AUG of TG was found in both modalities (12% with 30min exercise and 16% with 60min exercise). Therefore, in addition to exercise intensity, caloric expenditure (total work) is an important point in the reduction of the postprandial triglyceride curve, which also explains the present results where both sessions were matched for caloric expenditure. Importantly, a recent meta-analysis found that greater caloric expenditure during physical activity, regardless of intensity, is associated with health and correlates better with total energy expenditure (Jayedi et al., 2022).

Finally, the association between energy expenditure and triglyceride AUC has been described as very strong (Pearson et al., 2022). Strikingly, although energy expenditure was similar between the exercise protocols, triglyceride levels were lower at various times during the MI protocol. Our experimental design was based on a prescription that was 10% below and 10% above the second ventilatory threshold, resulting in a statistical difference in terms of respiratory exchange rate when comparing the protocols.

Importantly, this ensures that the protocols differed in the predominance of macronutrient oxidation, as MI had an oxidative predominance and HI had a glycolytic predominance. Considering that PPL is dependent on the rate of triglyceride storage or oxidation, it is possible that the MI induced greater

triglyceride oxidation at certain time points, since the predominance of activation of the oxidative metabolism affects the activity of triglycerides muscular absorption lipases, influencing its muscular availability for oxidation (Burns et al., 2015).

Notwithstanding that most adult studies report changes in the postprandial triglyceride curve with high energy expenditure (Maciel et al., 2022), over 450 kcal, moderate-to-high intensity, and over 40 minutes protocols, based on the present results, a higher caloric expenditure or exercise duration may be required to induce positive PPL responses in adolescents (Kim et al., 2014).

As clinical applications, we can highlight with this study that in adolescents, IM exercises are more effective in reducing PPL, making them an important tool to help prescribe exercise. Finally, the limitations of the study include that longer sessions may have provided different results, especially since the protocols were matched for energy expenditure, the assessment of only eutrophic adolescents and the maturation state, which was carried out by a self-assessment scale. In addition, our fasting period was 12 hours, and longer periods could induce different results. Therefore, future studies could investigate the activities of specific enzymes that may be different in this population, as well as longer exercise sessions.

Conclusions

The present study shows that fasting aerobic exercise of moderate and high intensity, compatible with calories, does not have major acute effects on the responsiveness of PPL in adolescents, being limited to reductions in IM at only two moments: 105 and 135 min. We suggest that future studies use a high-fat meal before the exercise protocols, thus avoiding fasted exercise, and also use more reliable maturation analysis tools.

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